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AGE, LENGTH, SEX, AND ABUNDANCE OF ARCTIC GRAYLING IN THE RICHARDSON CLEARWATER RIVER AND SHAW CREEK, 1988[1]

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ABSTRACT

Arctic grayling were captured by electrofishing within a 12.8 kilometer section of the Richardson Clearwater River in July 1988, and within a 1 kilometer section of the Tanana River at the mouth of Shaw Creek in April 1988. Population abundance in the Richardson Clearwater River was estimated at 4,599 Arctic grayling greater than 250 millimeters fork length, and at Shaw Creek, 6,080 Arctic grayling greater than 270 millimeters fork length. The majority of the two populations were adult fish with age 5 Arctic grayling being the predominant age class. Relative indices of abundance based on electrofishing catch rates showed a significant correlation to absolute population abundance in the Richardson Clearwater River.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Richardson Clearwater River, Shaw Creek, population abundance, age composition, size composition, harvest, fishing effort, Relative Stock Density, electrofishing, Tanana River drainage.

INTRODUCTION

The 19.2-km long Richardson Clearwater River is a spring-fed tributary to the Tanana River, approximately 43 km northwest of Delta Junction (Figure 1). The river is semi-remote and access is limited to riverboats. The nearest boat launch is 9 km up the Tanana River at Shaw Creek. Limited floatplane access is available at river kilometer 5. There are 17 summer cabins on the river. The river supports a recreational fishery on Arctic grayling *Thymallus arcticus*. Round whitefish, *Prosopium cylindraceum*, coho salmon, *Oncorhynchus kisutch*, and chum salmon, *Oncorhynchus keta*, are also present but are not presently utilized. The fishery is primarily conducted by summer residents and their guests. The fishery can be characterized as "blue ribbon" due to the availibilty of large fish, ease of fishing, the river's esthetics, and its semi-remoteness. Harvests have ranged from 2,822 to 798 Arctic grayling with a six year mean of 1,519 (Table 1). Angling effort has ranged from 1,365 to 596 man-days with a mean of 1,061 (Table 1). The majority of angling occurs in the river's lower 9.6 km.

As with other spring-fed systems in the area, most notably the Delta Clearwater River, the Richardson Clearwater River can be characterized by its clear waters, constant water temperatures and discharge (3 - 5°C; 8.5 - 11.3 m^3/s), and by the seasonal availability and mixed stock composition of its Arctic grayling population. Arctic grayling utilize the river strictly as a summer feeding area. The population is predominantly comprised of adult and sub-adult Arctic grayling that migrate into the river beginning in mid-May from spawning areas located in other waters. Three of these areas have been documented from tagging studies; Caribou and Rapids Creek in the Shaw Creek drainage and the Goodpaster River (Ridder 1984). Tack (1980) has summarized studies that show this migration is deliberate and characterized by strong homing behavior. Out-migration can begin as early as mid-August and is essentially complete by mid-November.

Shaw Creek is bog-fed, 112 km in length and is located 32 km northwest of Delta Junction (Figure 1). Since 1980, 8,000 Arctic grayling have been tagged in the Shaw Creek drainage, the majority of which were tagged as they migrated out of a major tributary, Caribou Creek, after spawning. Angler returns of 780 tags have identified six other recreational fisheries within 72 km of the mouth of Shaw Creek, ranging from the Little Salcha River to the Delta Clearwater River (Ridder 1985, and unpublished data). Ridder (1985) estimated that fish from Caribou Creek accounted for 30 to 50% of Arctic grayling abundance in the Richardson Clearwater River. Until 1987, when a season closure became effective, Shaw Creek's major fishery occurred in the spring on pre-spawning adult grayling congregating off the mouth awaiting ice break-up. This fishery was closed twice by Emergency Order in 1981 and 1985. Spring harvests have ranged from 4,343 fish in 1981 to 270 fish in 1986 (Table 2). Annual harvests from 1983 to 1986 have ranged from 2,584 fish in 1985 to 505 fish in 1986 (Table 3). From 1983 to 1986, the spring harvest has accounted for an average 58% of the annual harvest.

Studies in the mid 1980's (Holmes et al. 1986; Clark and Ridder 1987a, b) found that significant declines in Arctic grayling abundance and harvest rates had occurred in these and other waters of the Tanana River drainage. Results

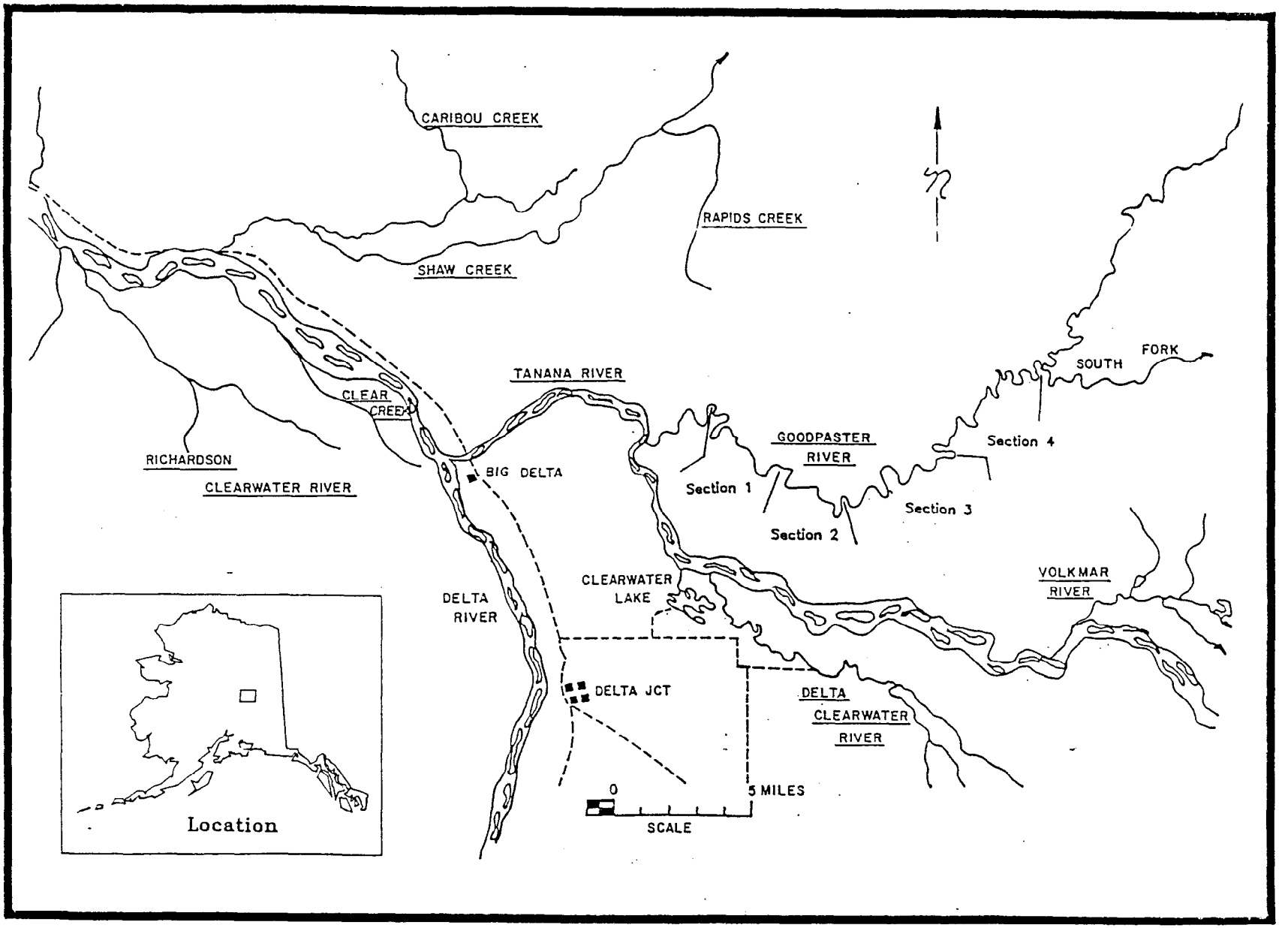

Figure 1. Map of the middle Tanana River drainage and study area.

Table 1. Estimated recreational Arctic grayling harvest and angling effort on the Richardson Clearwater River, 1981 - 1986[1].

Year	Effort		Harvest	CPUE[3]
	Anglers	Man-days[2]		
1981	NA[4]	916	1,562	1.65
1982	NA	1,365	1,729	1.27
1983	NA	1,349	2,822	2.09
1984	NA	1,080	1,376	1.27
1985	NA	NA	798	---
1986	289	596	827	1.39
Averages	289	1,061	1,519	1.43

[1] Data sources: 1986, Mills (1987); other years, Mills (unpubl.).
[2] Estimates of man-days includes effort expended for all species.
[3] CPUE = the number of Arctic grayling harvested per man-day.
[4] NA = data not available.

Table 2. Estimated spring recreational Arctic grayling harvest and angling effort[1] at the mouth of Shaw Creek from on site creel census surveys, 1974 - 1986[2].

Year	Effort		Harvest	CPUE[3]
	Man-days	Angler-hours		
1974	85	NA[4]	500	2.40
1975	200	NA	1,150	1.60
1981[5]	966	2,029	4,343	2.14
1982	555	1,172	979	0.87
1983	874	2,005	1,864	0.89
1984	1,095	2,292	913	0.41
1985[6]	372	970	1,533	1.58
1986	479	1,003	270	0.27
Averages	578	1,579	1,444	1.27

[1] Since 1987, spring fishery has been closed by Emergency Order and then by regulation till the first Saturday in June.
[2] Data sources: 1974 - 1975, Peckham (1976); 1981 - 1984, Ridder (1982, 1983, 1984, 1985); 1985, Holmes et al. (1986); 1986, Clark and Ridder (1987a).
[3] CPUE = the number of Arctic grayling harvested per angler hour.
[4] NA = data not available.
[5] Spring fishery closed by Emergency Order from 23 April to 15 May.
[6] Spring fishery closed by Emergency Order from 1 May to 15 May.

Table 3. Estimated recreational Arctic grayling harvest and angling effort on Shaw Creek from Statewide Harvest Surveys, 1983 - 1987[1].

Year	Effort		Harvest	CPUE[3]
	Anglers	Man-days[2]		
1983	NA[4]	2,495	2,297	0.92
1984	888	2,195	2,570	1.17
1985[5]	939	1,248	2,584	2.07
1986	1,313	2,003	505	0.25
1987[6]	607	797	567	0.71
Averages	937	1,748	1,705	0.98

[1] Data sources: Mills (1984-1988).
[2] Estimates of man-days includes effort expended for all species.
[3] CPUE = the number of Arctic grayling harvested per man-day.
[4] NA = data not available.
[5] Spring fishery closed by Emergency Order from 1 May to 15 May.
[6] Spring fishery closed by Emergency Order from 3 April to 5 June.

of a dynamic pool model indicated severe overfishing was occurring in some fisheries and that environmental conditions during the first year of life can significantly affect subsequent recruitment to the fisheries (Holmes et al. 1986). In response, regulation changes restricting harvest of Arctic grayling were made in 1987 for the Richardson Clearwater River, Shaw Creek, and other waters of the Tanana River drainage. These regulations limited the harvest to fish 305 mm total length or greater, restricted methods to unbaited artificial lures only, and imposed catch and release fishing during the spring spawning period. This study continued the monitoring and assessment of Arctic grayling stocks affected by regulation changes. The goal was to further the understanding of Arctic grayling life history and population dynamics.

The research objectives for 1988 were to estimate:

1) the abundance of Arctic grayling (≥ 150 mm fork length) in the Richardson Clearwater River and Shaw Creek; and

2) the age composition of the population of Arctic grayling (≥ 150 mm fork length) in the Richardson Clearwater River.

In addition, age composition of the population of Arctic grayling (≥ 150 mm FL) in Shaw Creek was estimated.

METHODS

Estimation of Absolute Abundance

In the Richardson Clearwater River, abundance of Arctic grayling was estimated with the modified Peterson formula of Bailey (1951, 1952). The binomial model of Bailey is most appropriate for the systematic sampling design used in this study; the population is assumed to be closed. In Shaw Creek, abundance of Arctic grayling was estimated using the generalized Jolly-Seber model (Seber 1982). This population in Shaw Creek is assumed to be open and the sampling design is a single capture event.

Richardson Clearwater River:

In the Richardson Clearwater River, the abundance of Arctic grayling was estimated in the lower 12.8 km of the river. The upper 6.4 km was not included because its small size prevented safe boat-mounted electrofishing, and few fish have been found there in previous surveys (Ridder field notes). The sampled river was divided into three sections based on distinct geographical differences (Figure 2). These sections were electrofished once a day with intervals of at least one day between sampling events. Section 2 is separated from the other two sections by large pools (270 and 810 m long) formed by old beaver dams. Section 1 extends 4.8 km upstream from the mouth to the longest "pool"; Section 2 extends the same distance upstream from the head of this "pool" to the second "pool"; Section 3 is 3.2 km long and extends upstream to the river's second tributary. Ridder (1983) described these sections in more detail.

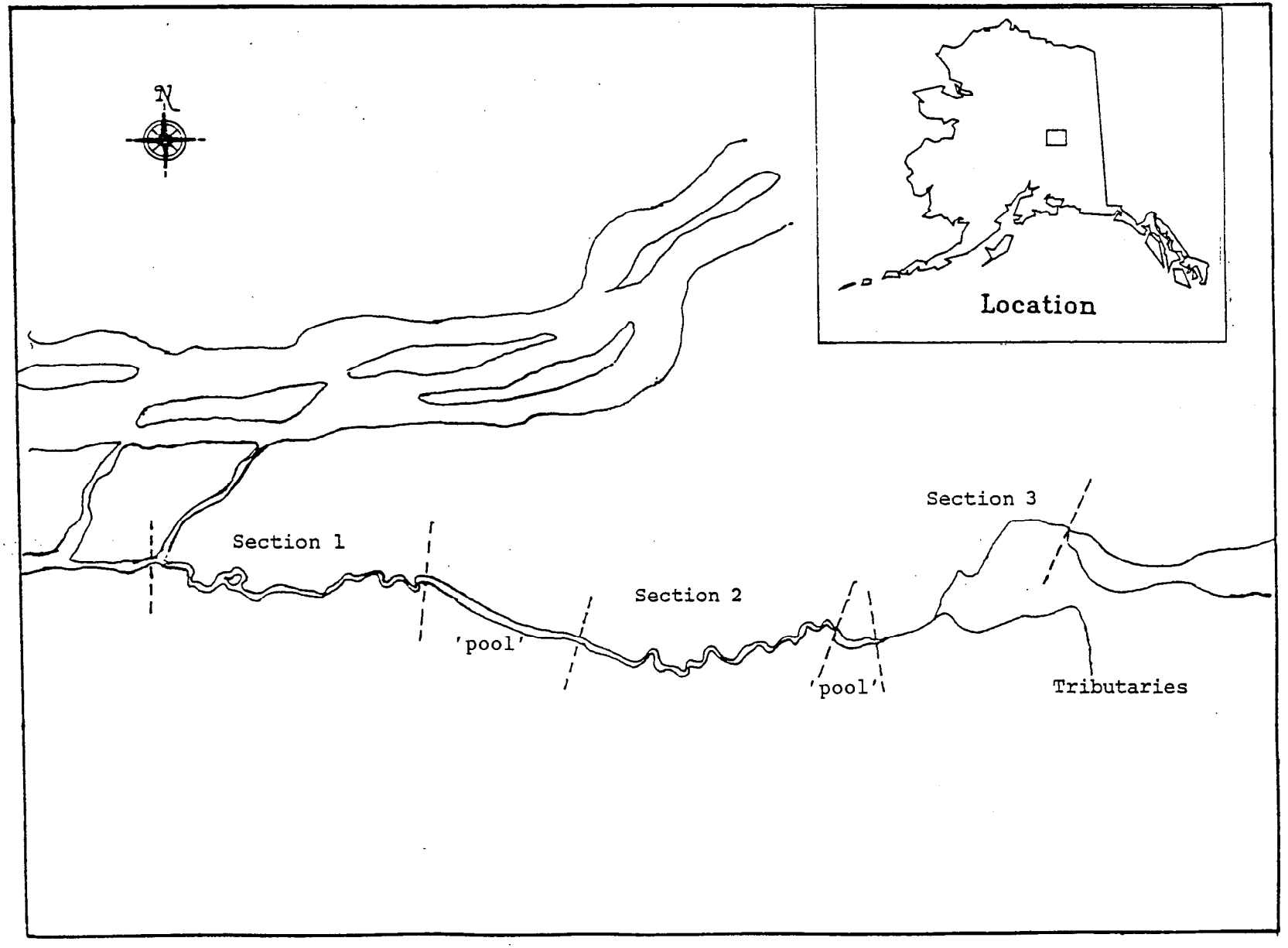

Figure 2. Map of the Richardson Clearwater River and study sections.

Sampling started at the upstream end of a section and consisted of an electrofishing boat traveling downstream collecting as many Arctic grayling as possible. The boat had a crew of three and used a pulsed DC variable voltage pulsator with four 1.5 m long steel cables, 13 mm in diameter (flexible conduit) as anodes and the unpainted bottom of the boat as the cathode. At the end of an approximately 20 minute run or the capture of 40 fish, all captured fish were measured to the nearest 1 mm of fork length (FL). Those greater than 149 mm FL were tagged with Floy FD-67 anchor tags. A partial upper caudal fin clip was used as a secondary mark to determine tag loss. The fish were then released individually throughout the section they were captured in. Resumption of sampling started at the end of the previous run. Data collection was segregated by section to facilitate analysis of migration between sections.

While the stated objective for the Richardson Clearwater River was to estimate the abundance of Arctic grayling greater than 149 mm FL, insufficient numbers of small fish were captured (Appendix Table 1). Instead, the abundance was estimated for fish greater than 249 mm FL. This change allowed direct comparisons to 1987 estimates of abundance which also addressed fish greater than 249 mm (Clark and Ridder 1988). Three sampling events were conducted from 5 through 8 July and constituted the marking stage. The recapture stage was made up of three sampling events conducted from 13 through 19 July. The necessary assumptions for an unbiased estimate are (from Seber 1982):

1) the population in the study area must be closed;

2) no tags can be lost between samples;

3) all fish have the same probability of capture during the first sample or during the last sample or marked fish must completely mix with unmarked fish between samples;

4) marking must not influence fish behavior between samples; and,

5) mortality is the same for both marked and unmarked fish between samples.

The Kolmogorov-Smirnov test showed that there was no significant recruitment by growth or immigration during the experiment indicating fulfillment of assumption 1. Fin-clipping, in addition to tagging, satisfied the second assumption. The four day hiatus between the marking and recapture events facilitated mixing of marked and unmarked fish. However, size selective gear bias during sampling events was suggested in two of three tests. A Kolmogorov-Smirnov two-tailed test (Conover 1980) applied to all fish recaptured and not recaptured showed a marginal difference in capture probabilities and size selectivity during the marking event ($D = 0.217$, $P = 0.053$). A contingency test applied to the same groups divided into two length strata (250-349 and ≥ 350 mm FL) showed significant differences ($\chi^2 = 6.96$, $df = 1$, $P < 0.05$; Appendix Table 1). A Kolmogorov-Smirnov two-tailed test on the lengths of all fish captured during the marking event and those during the recapture event showed no significant differences ($D = 0.074$, $P = 0.205$). The estimate was accordingly stratified by length. Length strata

were chosen on the basis of recaptured to marked ratios (Appendix Table 1) and were the same strata chosen in 1987 (Clark and Ridder 1988).

The abundance estimate was further stratified by river section. Sections 1 and 2 were combined due to low numbers of recaptures within length strata in Section 1. Although there were equal probabilities of capture during the recapture event among all three river sections ($\chi^2 = 2.38$, df = 2, $P > 0.05$), population stratification by size among river sections was apparent and separate river section estimates were appropriate. Relative Stock Density indices were significantly different between all three sections and between Section 3 and the lower two sections ($\chi^2 = 301.84$, df = 4, $P < 0.05$; $\chi^2 = 172.47$, df = 2, $P < 0.05$, respectively; Appendix Table 2). Age compositions were likewise significantly different between the same section groupings ($\chi^2 = 101.75$, df = 8, $P < 0.05$; $\chi^2 = 78.72$, df = 4, $P < 0.05$, respectively; Appendix Table 3).

Since the section abundance estimates were independent within each stratum, the whole river abundance estimate and its variance were calculated as the sum of the strata estimates. It was assumed that the underlying probability distribution of the estimate was normal and thus a confidence interval was calculated as:

$$(1) \qquad \hat{N} \pm 1.96 * SE[\hat{N}]$$

where: $\hat{N}$ = the abundance estimate; and,
SE = the standard error of the estimate.

Shaw Creek:

In Shaw Creek, the absolute abundance of Arctic grayling during 1987 was estimated with the generalized Jolly-Seber model (Seber 1982). This model has been used since 1981 to estimate the abundance of age 4 (≥ 200 mm FL) and older Arctic grayling (Clark and Ridder 1987b; Clark and Ridder 1988). Arctic grayling were tagged during previous years (June 1980 through 1987) at Caribou Creek, the major spawning tributary of Shaw Creek (Figure 1). Since there is at least one other known spawning area in the drainage at Rapids Creek (Ridder 1983), abundance estimation of the Shaw Creek stock using the tagging at Caribou Creek would only be possible when the whole stock is accessible to sampling.

In April after the ice had gone out of the Tanana River but before the ice break-up of Shaw Creek, Arctic grayling are concentrated at the mouth of Shaw Creek awaiting ice break-up and access to upstream spawning areas. At this time, Arctic grayling were captured with a pulsed DC electrofishing boat (described above). During one sampling event, four electrofishing runs (two runs along each bank) were made along a reach 0.8 km above and below the mouth of Shaw Creek. Prior to 1987, recaptures of tagged fish were obtained from creel censusing the spring fishery in the same location (Ridder 1985). Since the fishery was closed in 1987, recovery of tags has been conducted by electrofishing during the time the fishery would have been occurring.

Unlike previous applications of the Jolly estimator that estimated the population greater than 199 mm FL (Clark and Ridder 1988), the abundance estimate presented in this report pertains to the population greater than 270 mm FL. Due to the size selectivity of capture methods for the marking event (weir) and the recapture event (hook and line and electrofishing), the sum of all samples since 1986 were significantly different in size compositions ($\chi^2 = 317.23$, df = 3, $P < 0.05$; Appendix Table 4). Including fish less than 270 mm FL in the mark sample (nearly absent in the recapture sample and including no tag recaptures) would produce a large bias in the parameter estimates. Data prior to 1986 are likely to be similarly affected. Holmes et al. (1986) reports that the spring fishery harvests predominantly adult Arctic grayling which comprised 85% of the 1985 harvest. Estimates derived from these early data are not included pending computer entry and restructuring of the data base.

In limiting the available data base (1985 - 1988) to fish greater than 269 mm FL, only one recapture of a 1985 mark was found in 1986 at Shaw Creek. Clark and Ridder (1988) also reported on the paucity of recaptures from all years in this sample (n = 4; including fish 200 - 269 mm FL) and stated that the condition seriously biased parameter estimates for 1985 and 1986. With the model requiring large sample sizes, this recapture sample was also not included in the model. With the available data limited to three years, sampling in 1988 provided one abundance estimate pertinent to the time of tagging in 1987.

Estimation of Relative Abundance

In the Richardson Clearwater River, sampling was conducted in conjunction with the absolute abundance estimation described earlier and used the same river sections. On a given day, one run was made through each section collecting as many electrofished Arctic grayling as possible. The timing of each run was recorded by a stop watch to the nearest 1 minute. Runs were separated by at least one day. The total number of Arctic grayling captured in a run was the catch rate (CPUE) and was used as an index to estimate relative abundance. CPUE data were collected for each of the three river sections. Although six runs were made during the abundance estimation, only those data from five runs were used to estimate CPUE. The third run in Sections 1 and 2 was excluded because it occurred the day after the second run. The catch rate in the third run indicated an apparent downstream displacement of fish from Section 2 to Section 1 (Appendix Table 4). This apparent displacement of fish by repetitive electrofishing has been demonstrated in other studies (Ridder 1983; Clark 1989; Ridder in press). Crew members and fishing gear were the same during all runs.

Bootstrapping was performed to estimate mean CPUE and the variance of mean CPUE. This estimation technique was used because of a small sample size and a concern that the assumption of a normally distributed variance would be violated. Past studies (Clark and Ridder 1988) have shown mean CPUE to be more closely related to the Poisson distribution (variance nearly equal to the mean and asymmetric confidence intervals). Bootstrap mean CPUE was

approximated by Monte Carlo methods, randomly sampling the mean of five data points (with replacement) 1,000 times as follows:

$$(2) \qquad CPUE_B = \frac{\sum_{j=1}^{B} \left\{ CPUE_j = \left[\Sigma\, C_{Bi} \right] \div 5 \right\}}{B}$$

where: B = the number of bootstrap samples;
i = 1, 2, 3, 4, 5 random draws from the five original data points (with replacement);
C_{Bi} = the ith random draw from the original data;
$CPUE_B$ = the bootstrap mean catch rate; and,
$CPUE_j$ = the catch rate of the jth bootstrap iteration.

The bootstrap variance was approximated by the standard variance formula:

$$(3) \qquad V(CPUE_B) = \left[\sum_{j=1}^{B} (CPUE_j - CPUE_B)^2 \right] + (B - 1)$$

where: $V(CPUE_B)$ = the bootstrap variance of $CPUE_B$.

A non-parametric 95% confidence interval was estimated for $CPUE_B$ by the percentile method of Efron (1981). Bootstrap mean CPUE was calculated for each of the three river sections and with the combined data sets for the whole river estimate.

A correlation coefficient, r, was calculated between relative and absolute abundance estimates with the formula:

$$(4) \qquad r = \frac{\Sigma\, x_k y_k}{(\Sigma x_k^{\,2}\ \Sigma y_k^{\,2})^{1/2}}$$

where: x_k = total catch from the first electrofishing run in year k;
y_k = estimated population abundance in year k.

Although equation 4 requires that the two samples to be taken from normally distributed populations, the underlying distributions of CPUE and abundance estimates were not known, but assumed to be non-normal. No statistical significance can be attributed to these correlation statistics until more samples are collected and the empirical distributions known.

Estimation of Age and Size Composition

A minimum of two scales from all initial captures of Arctic grayling greater than 149 mm FL were removed from an area four to six scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were processed by cleaning in a hot solution of common dish detergent, inspected for regeneration, and then mounting the two best scales from each fish on

gummed cards. The cards were used to make impressions of the scales on 20 mil acetate film using a Carver press at 137,895 kPa heated to a temperature of 97°C. Ages were determined by replicate readings using a microfiche reader.

The proportion of Arctic grayling in each age class was estimated as:

$$(5) \qquad \hat{p}_g = \frac{y_g}{n}$$

where:

y_g = the number of Arctic grayling of age g in the sample; and,
n = the number of Arctic grayling in the sample.

The unbiased variance of this proportion is:

$$(6) \qquad V[\hat{p}_g] = \frac{\hat{p}_g\ (1-\hat{p}_g)}{n - 1}$$

Age class composition of Arctic grayling in the Richardson Clearwater River was adjusted for bias due to length selectivity of the electrofishing boat and population stratification within the river. Within each length stratum and river section, the proportion of each age class and its variance were first estimated with equations 5 and 6. The age composition in Section 3 and Section 1 and 2 combined was then estimated separately with the following equations. The age composition of the population (all Sections combined) was estimated with the same equations (7 through 10) substituting "Section" for "stratum". The estimated abundance of age g in the population (Section) is:

$$(7) \qquad \hat{N}_i = \sum_{h=1}^{K} \hat{p}_{gh}\ \hat{N}_h$$

where:

N_g = the estimated abundance of age g;
p_{gh} = the proportion of fish of age g in stratum h;
N_h = the estimated abundance in stratum h; and,
K = 1, 2 length strata.

The variance of N_g is a sum of the exact variance of a product from Goodman (1960):

$$(8) \qquad V[\hat{N}_g] = \sum_h (V[\hat{p}_{gh}]\hat{N}_h^2 + V[\hat{N}_h]\hat{p}_{gh}^2 - V[\hat{p}_{gh}]V[\hat{N}_h])$$

The estimated proportion of the population that belongs to age g ($\hat{p}_g$) is:

(9) $\hat{p}_g = \hat{N}_g/\hat{N}$, where: $N = \Sigma \hat{N}_h$.

The variance of the estimated proportion can be approximated with the delta method (see Seber 1982):

$$(10) \quad V[\hat{p}_g] = \Sigma V[\hat{p}_{gh}] \left\{ \frac{\hat{N}_h}{N} \right\}^2 + \frac{\Sigma V[N_h] (p_{gh} - p_g)^2}{N^2}$$

Length-at-age information was used to characterize growth of adult Arctic grayling. Mean lengths were calculated as the arithmatic mean fork length at each age of all Arctic grayling captured.

Size composition of intial captures is described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories for Arctic Grayling were: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and "trophy" (greater than 560 mm FL). RSD indices were estimated with equations 1 through 8, substituting the RSD categories for age classes.

Sex and Maturity

Since sampling at Shaw Creek was conducted during the pre-spawning concentration of Arctic grayling, sex and maturity were readily determined by either sexual dimorphism or the presence of milt or eggs. Dimorphism is evident in differences in length of the dorsal fin (the male dorsal fin usually extends to the adipose fin whereas the female dorsal fin is noticably shorter) and the swelling of the anal vent and abdomen fullness (gravid) or flaccidity (spawned out) in females. Some error was associated with the use of these morphological characteristics as the sole determinator of sex. For example, at the time of sampling, small males may have been classed as juveniles since their dorsal fin may not have reached the adipose and they may not be able to give milt. Sex ratios were presented as the ratio of the number of males to females.

RESULTS AND DISCUSSION

Richardson Clearwater River

Absolute abundance of Arctic grayling in the Richardson Clearwater River continued to increase in 1988 from the historical low estimated in 1986 (Appendix Table 5). The estimated abundance of fish greater than 249 mm FL in 1988 was 4,599 (SE = 751) with a 95% confidence interval of 3,127 to 6,071 (± 32%) (Table 4). The 9.6 km of the lower river representing Sections 1 and 2 had an estimated 2,406 Arctic grayling or 251 per km (Table 4). The 3.2 km upper river section, Section 3, had an estimated 2,193 Arctic grayling or 685 per km (Table 4).

Table 4. Estimated abundance of Arctic grayling (≥ 250 mm FL) in the Richardson Clearwater River, 5 July through 19 July 1988.

Length Category	Marks	Catch	Recaps	N[1]	$\hat{SE}$[2]	CV(%)[3]
Section 1 and 2						
250-349	99	199	6	1,697	564	33.3
≥350	93	121	15	709	147	20.7
Total	192	240	21	2,406	583	24.2
Section 3						
250-349	147	185	13	1,953	463	23.7
≥350	40	47	7	240	66	27.6
Total	187	232	20	2,193	468	21.3
River Total	379	472	41	4,599	748	16.3

[1] Modified Peterson estimate (Bailey 1951, 1952).
[2] Standard error of the estimate.
[3] Coefficient of variation.

As with the absolute abundance estimates, the relative abundance estimate in 1988 showed an increase over those found in 1986 and 1987 (Appendix Table 5). The relative abundance, or CPUE (number of Arctic grayling caught in one electrofishing run through a section), for fish greater than 249 mm FL had a mean value of 162.9 in 1988 (Table 5). The CPUE for all Arctic grayling caught was 171.9 (Appendix Table 6). By river section, the mean CPUE for fish greater than 249 mm FL was 18.0 in Section 1, 51.9 in Section 2, and 92.9 in Section 3 (Table 5). The variation for these estimates was greatest in Section 3 (98.3) and the lowest in Section 1 (1.9) (Table 5). This variabilty within sections, i.e. increasing from the lower to upper sections, has been consistent in two of the three years that mean CPUE has beeen calculated.

The six electrofishing passes on the river represented a total of 13.4 hours spent capturing 932 grayling for a catch rate of 70 grayling per electrofishing hour (Appendix Table 7). The five runs represented in the relative abundance estimation took 11.6 hours to catch 860 grayling or 74 grayling per hour. These figures compare to the 38, 19, and 73 Arctic grayling caught per hour in 1987, 1986, and 1985, respectively.

Since 1977, the number of Arctic grayling captured in one downstream pass with an electrofishing boat has been used as an index of relative abundance in monitoring population trends (Ridder 1985). Correlation coefficients (r) were calculated between relative and absolute abundance estimates from the whole river ($n = 4$) and from Section 3 ($n = 7$) (Appendix Table 5; Figure 3). Correlation between the two abundance estimates in Section 3 was high ($r = 0.97$) as it was for the whole river ($r = 0.98$). Considering these correlations, relative indices can be considered a reliable and cost-effective method for monitoring the abundance of Arctic grayling in the Richardson Clearwater River given that gear and sampling time are held constant.

A total of 662 Arctic grayling were sampled for age and size composition in the Richardson Clearwater River. Age 5 was the most numerous age class comprising 32% of the sample (Table 6). Ages 6 through 9 comprised 10% to 16% of the sample. Juvenile fish of ages 1 through 4 comprised 7% of the sample. When age composition was adjusted to compensate for length bias in the electrofishing sample, ages 8 and older decreased in proportion, while ages 7 and younger tended to increase in proportion. (With the adjustment, ages 1 and 2 were not represented; Table 6). Age 5 was predominant in the adjusted sample, comprising 36% (Table 6). Ages 7 and 8 were similar at 11 and 13%. RSD indices reflected the high abundance of older grayling in the river with 30% of the population in the preferred category and only 15% in the stock category (Table 7). Stock sized fish were more abundant in the lower two sections (29% of the sample) than the upper section (2%) while the inverse was true of the larger fish (15 and 44%, respectively).

Shaw Creek

Five days were spent electrofishing the Tanana River approximately 0.8 km above and below the mouth of Shaw Creek from 18 to 22 April. As in 1987 (Clark and Ridder 1988), quickly rising water levels and increasing turbidity made further sampling unproductive. A total of 357 Arctic grayling was captured during 7.9 hrs of electrofishing. The majority of captures occurred

Table 5. Electrofishing catch rate (CPUE)[1] statistics for Arctic grayling greater than 249 mm FL from each of five electrofishing runs through three sections of the Richardson Clearwater River, 5 through 19 July 1988[2].

Date	Run	Catch Rate			
		Section 1	Section 2	Section 3	Total
5 July	1	17	43	122	182
7 July	2	23	46	72	141
8 July	3	NA[3]	---	---	---
13 July	4	17	69	108	194
15 July	5	15	50	70	135
19 July	6	18	66	84	168
mean		18.0	51.9	92.9	162.9
variance		1.9	20.5	98.3	125.2
95% C.I.		15.8-20.6	45.0-60.0	78.0-108.8	145.6-181.0

[1] CPUE is the number of grayling caught in one electrofishing run through a section.
[2] Summary statistics developed from bootstrap methods (Efron 1981 and 1982).
[3] NA = not applicable to CPUE estimate; see Methods and Appendix Table 7.

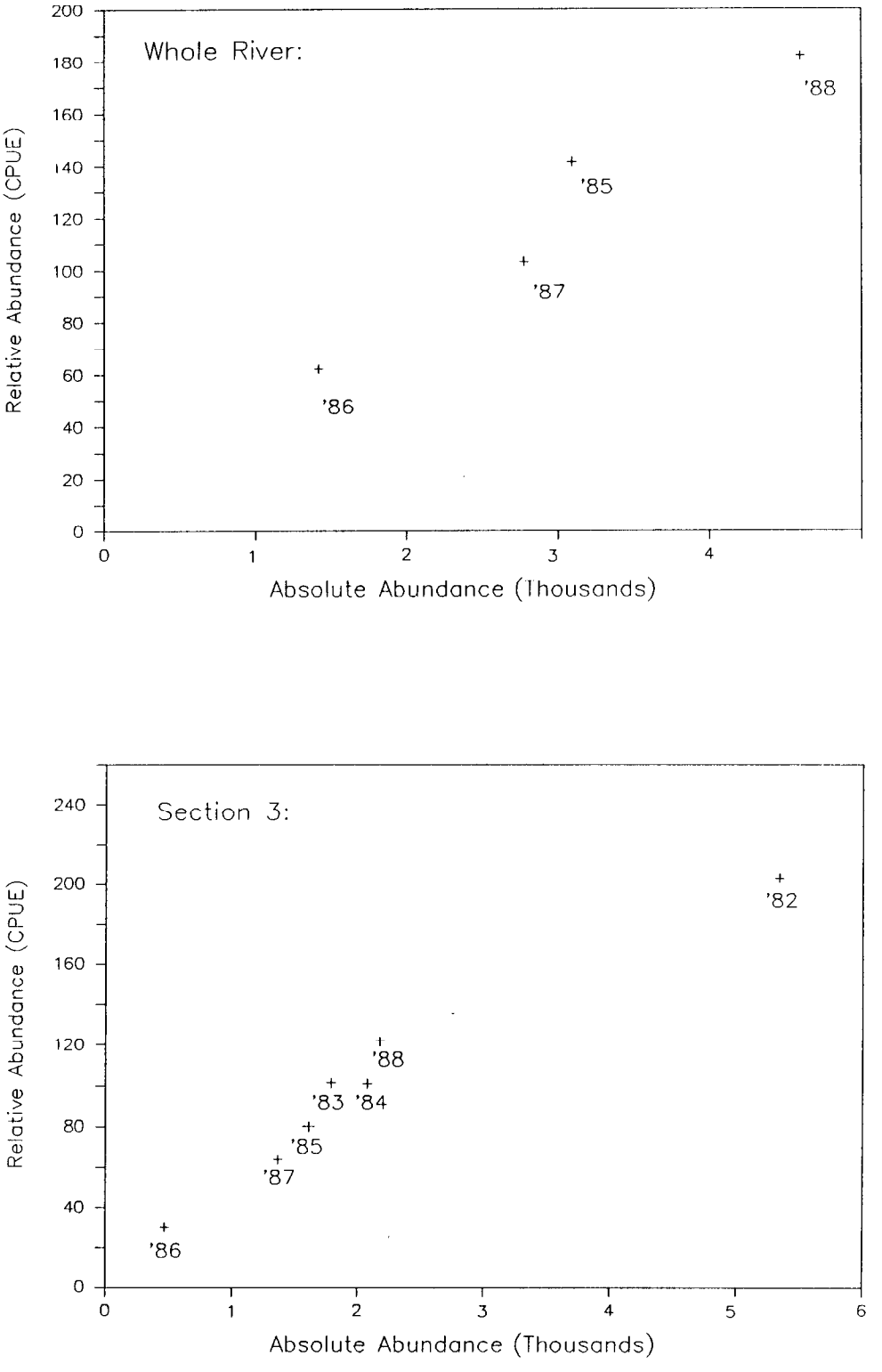

Figure 3. Scatter plots of relative abundance versus absolute abundance for two areas of the Richardson Clearwater River, 1982 through 1988.

Table 6. Estimates of the sampled and adjusted[1] proportional contribution of each age class and sampled mean fork length (mm) at age for Arctic grayling captured in the Richardson Clearwater River, 5 July to 15 July 1988.

	Sampled:		Adjusted:		Fork Length	
Age	n[2]	p[3]	p[4]	SE[5]	Mean	SD[6]
1	1	0.002	0.000	---	100	---
2	1	0.002	0.000	---	190	---
3	4	0.006	0.002	0.002	245	15
4	38	0.057	0.051	0.010	258	20
5	212	0.320	0.358	0.033	281	24
6	104	0.157	0.205	0.022	313	22
7	73	0.110	0.114	0.014	345	24
8	95	0.144	0.127	0.017	356	21
9	68	0.103	0.077	0.015	377	24
10	36	0.054	0.036	0.010	398	20
11	17	0.026	0.016	0.006	406	17
12	12	0.018	0.013	0.005	408	32
13	1	0.002	0.001	0.001	446	---
Total	662	1.000	1.000		324	51

[1] Age composition is adjusted to compensate for length bias in the electrofishing sample.
[2] n = sample size.
[3] p = proportion of sampled grayling.
[4] p = adjusted proportion of grayling (≥ 250 mm) in stock.
[5] SE = standard error of the adjusted proportion.
[6] SD = standard deviation of the mean fork length.

Table 7. Summary of sampled and adjusted Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled in the Richardson Clearwater River, 5 through 18 July 1988.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
Section 1 and 2					
Number sampled	118	230	97	0	0
Sampled RSD[2]	0.265	0.517	0.218	---	---
Adjusted RSD[3]	0.288	0.561	0.151	---	---
Standard Error[4]	0.025	0.032	0.035	---	---
Section 3					
Number sampled	7	163	244	0	0
Sampled RSD	0.017	0.394	0.589	---	---
Adjusted RSD	0.023	0.537	0.440	---	---
Standard Error	0.009	0.066	0.068	---	---
Total					
Number sampled	125	393	341	0	0
Sampled RSD	0.146	0.458	0.397	---	---
Adjusted RSD	0.149	0.549	0.302	---	---
Standard Error	0.005	0.007	0.007	---	---

[1] Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

[2] RSD calculated directly from the number sampled.

[3] RSD adjusted for Arctic grayling ≥ 250 mm FL due to bias in length selectivity of the electrofishing boat.

[4] Standard error of the adjusted RSD.

upstream of the creek mouth. Of the 336 individual fish captured, 33 were recaptures of fish tagged in previous years. Twenty-three fish were initially tagged at Caribou Creek and 10 fish were tagged in April 1987 in the Tanana River by Shaw Creek.

The Jolly-Seber abundance estimate in Shaw Creek in April 1987 was 6,080 Arctic grayling greater than 270 mm FL (SE = 3,596, CV = 59.1%). The survival estimate from 1986 to 1987 was 0.76 (SE = 0.39, CV = 51.3%). This estimate compares with the 1987 Peterson estimate for Shaw Creek of 10,520 Arctic grayling greater than 289 mm FL (SE = 3,881, CV = 36.9%; Clark and Ridder 1988).

Age 5 was the most numerous age class comprising 31% of the 318 Arctic grayling sampled for age in 1988 (Table 8). The compositions of ages 6 through 8 were similar and ranged from 13 to 15%. Age 4 and younger fish made up 11% of the sample. This sample was represented by fewer older aged fish than in 1987. Forty-one percent of the sample were age 7 and older compared to 81% of the 1987 sample.

Adults (n = 176) made up 52% of the 336 Arctic grayling sampled. Two percent of the adults and 36% of the total sample were less than 270 mm, or stock-sized fish (Table 9). Of the adults, males were generally larger than females. Fifty-two percent of males and 30% of females were in the preferred category, or greater than 340 mm.

Mean lengths at age ranged from 138 mm FL for age 2 Arctic grayling to 413 mm for an age 12 fish (Table 10). Mean lengths at age were generally larger for the adult component of a cohort than for the subadults.

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Table 8. Estimated proportional contribution of each age class for Arctic grayling in the total and adult sample collected off the mouth of Shaw Creek, 18 through 22 April 1988.

	Total Catch			Adult Catch		
Age Class	n[1]	p[2]	SE[3]	n	p	SE
2	2	0.006	0.004	0	---	---
3	11	0.035	0.010	0	---	---
4	23	0.072	0.015	0	---	---
5	100	0.314	0.026	11	0.068	0.020
6	49	0.154	0.020	24	0.148	0.028
7	41	0.129	0.019	39	0.241	0.034
8	43	0.135	0.019	41	0.253	0.034
9	22	0.069	0.014	21	0.130	0.026
10	18	0.057	0.013	18	0.111	0.025
11	8	0.025	0.009	7	0.043	0.016
12	1	0.003	0.003	1	0.006	0.006
Total	318	1.000		162	1.000	

[1] n = sample size.
[2] p = proportion.
[3] SE = standard error of the proportion.

Table 9. Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled off the mouth of Shaw Creek, 18 through 22 April 1988.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
All					
Number sampled	122	133	81	0	0
RSD	0.363	0.396	0.241	---	--
Standard Error	0.026	0.027	0.023	---	--
Adults					
Number sampled	4	96	76	0	0
RSD	0.023	0.545	0.432	---	--
Standard Error	0.011	0.038	0.037	---	--
Males					
Number sampled	1	48	54	0	0
RSD	0.010	0.466	0.524	---	--
Standard Error	0.010	0.049	0.049	---	--
Females					
Number sampled	3	48	22	0	0
RSD	0.041	0.658	0.301	---	--
Standard Error	0.023	0.056	0.054	---	--

[1] Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

Table 10. Mean fork length (mm) at age for Arctic grayling by sex, collected off the mouth of Shaw Creek, 18 through 22 April 1988.

	Total			Male			Female		
Age Class	n[1]	Mean	SD[2]	n	Mean	SD	n	Mean	SD
2	2	138	7	0	---	---	---	---	---
3	11	184	13	0	---	---	---	---	---
4	23	224	20	0	---	---	---	---	---
5	100	254	27	5	310	32	6	276	14
6	49	289	19	16	302	16	8	291	17
7	41	317	28	19	335	21	20	303	25
8	43	342	22	25	345	23	16	336	20
9	22	357	16	13	358	18	8	354	15
10	18	372	27	13	375	29	5	364	21
11	8	398	23	4	408	8	3	373	12
12	1	413	---	1	413	---	0	---	---
Total	318	293	57	96	343	34	66	320	34

[1] n = sample size.
[2] SD = sample standard deviation.

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APPENDIX

Appendix Table 1. The number of Arctic grayling by 25 mm FL groups that were marked, caught, recaptured, and their recapture rate (R/M) in a Peterson experiment in the Richardson Clearwater River, 5 through 19 July 1988.

Length Group	Marked	Caught	Recaptured	R/M
150 - 174	0	0	---	---
175 - 199	0	2	---	---
200 - 224	1	1	0	0
225 - 249	25	16	1	0.040
250 - 274	57	50	2	0.035
275 - 299	68	86	7	0.103
300 - 324	64	98	6	0.094
325 - 349	55	73	6	0.109
350 - 374	62	65	9	0.145
375 - 399	39	63	7	0.179
400 - 424	27	29	6	0.222
425 - 449	7	7	0	0
Total	405	490	42	0.103

Appendix Table 2. Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled in three sections of the Richardson Clearwater River, 5 through 19 July 1988.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
Section 1					
Number sampled	83	59	18	0	0
RSD	0.519	0.369	0.113	---	---
Standard Error	0.040	0.038	0.025	---	---
Section 2					
Number sampled	35	171	79	0	0
RSD	0.123	0.600	0.277	---	---
Standard Error	0.019	0.029	0.027	---	---
Section 3					
Number sampled	7	163	244	0	0
RSD	0.017	0.394	0.589	---	---
Standard Error	0.006	0.024	0.024	---	---
Total					
Number sampled	125	393	341	0	0
RSD	0.146	0.458	0.397	---	---
Standard Error	0.012	0.017	0.017	---	---

[1] Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):
- Stock - 150 mm
- Quality - 270 mm
- Preferred - 340 mm
- Memorable - 450 mm
- Trophy - 560 mm

Appendix Table 3. Estimates of the proportional contribution of each age class of Arctic grayling greater than 249 mm FL captured in each of three sections of the Richardson Clearwater River, 5 through 19 July 1988.

	Section 1			Section 2			Section 3			Total		
Age Class	n[2]	p[3]	SE[4]	n	p	SE	n	p	SE	n	p	SE
3	0	---	---	1	0.005	0.005	0	---	---	1	0.002	0.002
4	10	0.097	0.029	10	0.050	0.015	7	0.022	0.008	27	0.043	0.008
5	61	0.592	0.048	72	0.360	0.034	55	0.173	0.021	188	0.303	0.018
6	12	0.117	0.032	43	0.215	0.029	49	0.154	0.020	104	0.167	0.015
7	6	0.058	0.023	23	0.115	0.023	44	0.138	0.019	73	0.118	0.013
8	8	0.078	0.026	25	0.125	0.023	61	0.192	0.022	94	0.151	0.014
9	2	0.019	0.014	16	0.080	0.019	50	0.157	0.020	68	0.110	0.013
10	2	0.019	0.014	7	0.035	0.013	27	0.085	0.016	36	0.058	0.009
11	1	0.010	0.010	2	0.010	0.007	14	0.044	0.012	17	0.027	0.007
12	0	---	---	1	0.005	0.005	11	0.035	0.010	12	0.019	0.006
13	1	0.010	0.010	0	---	---	0	---	---	1	0.002	0.002
Total	103	1.000		200	1.000		318	1.000		621	1.000	

[1] All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1984); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

[2] n = sample size.

[3] p = proportion.

[4] SE = standard error of the proportion.

Appendix Table 4. Number of Arctic grayling captured (N) and recaptured[1] (R) in four length groups (mm FL) at Shaw and Caribou Creeks, 1985 through 1988.

	Shaw Creek						Caribou Creek		
	1986		1987		1988		1985	1986	1987
Group	N	R	N	R	N	R	N	N	N
200 - 249	3	0	12	0	67	0	71	270	277
250 - 259	25	0	4	0	45	0	64	74	130
270 - 349	135	2	101	13	154	8	182	300	283
>349	21	2	147	24	60	15	9	68	60
Total	184	4	264	37	326	23	326	712	750

[1] Recaptures include fish tagged at Caribou Creek from 1980 through 1988.

Appendix Table 5. Relative (CPUE[1]) and absolute abundance estimates for Arctic grayling in the Richardson Clearwater River, July, 1980 through 1988[2].

	Whole River			Section 3		
		Absolute Abundance			Absolute Abundance	
Year	CPUE	N	95% CI	CPUE	N	95% CI
1980	170	ND[3]		NA[4]	ND	
1981	167	ND		NA	ND	
1982	324	ND		203	5,340	3,028 - 10,680
1983	220	ND		103	1,792	1,016 - 3,460
1984	138	ND		101	2,076	1,148 - 4,520
1985	142	3,114	1,939 - 4,289	83	1,610	974 - 2,876
1986	62	1,418	786 - 2,837	30	468	191 - 1,170
1987[5]	103	2,775	1,653 - 3,896	64	1,368	476 - 2,260
1988[5]	182	4,599	3,127 - 6,071	122	2,193	1,274 - 3,112

[1] CPUE = the total catch of Arctic grayling made in the first electrofishing run through a section (river).
[2] Data is from Ridder 1985; Holmes et al 1986; and Clark and Ridder 1987, 1988.
[3] ND = not done.
[4] NA = not available.
[5] Data is for fish greater than 249 mm FL only.

Appendix Table 6. Electrofishing catch rate (CPUE)[1] statistics for all Arctic grayling captured in each of five electrofishing runs through three sections of the Richardson Clearwater River, 5 through 19 July 1988[2].

Date	Run	Catch Rate			
		Section 1	Section 2	Section 3	Total
5 July	1	22	48	122	192
7 July	2	29	46	72	147
8 July	3	NA[3]	---	---	---
13 July	4	26	69	108	203
15 July	5	20	56	70	146
19 July	6	21	67	84	172
mean		24.2	54.7	92.9	171.9
variance		2.5	16.5	98.3	128.9
95% C.I.		21.6-26.6	48.4-61.8	78.0-108.8	155.4-189.6

[1] CPUE is the number of grayling caught in one electrofishing run through a section.
[2] Summary statistics developed from bootstrap methods (Efron 1981 and 1982).
[3] NA = not applicable to CPUE estimate; see Methods, Appendix Table 7.

Appendix Table 7. Catch, mortality, and time (minutes) statistics from six electrofishing runs through through three sections of the Richardson Clearwater River, 5 through 19 July 1988.

Section	Date	Run	Time	Catch			Mortality	CPUE[1]
				Total	≥200mm	≥250mm		
1	5 July	1	42	22	22	17	0	31
	7 July	2	47	29	29	23	0	37
	8 July	3	53	52	51	42	0	59
	13 July	4	43	26	25	17	0	36
	15 July	5	49	20	20	15	0	35
	19 July	6	43	21	21	18	1	39
Total			277	170	168	132	1	37
2	5 July	1	51	48	48	43	1	57
	7 July	2	54	46	46	46	2	51
	8 July	3	51	20	20	19	0	24
	13 July	4	53	69	69	69	0	78
	15 July	5	58	56	56	50	0	58
	19 July	6	60	67	67	66	1	67
Total			327	306	306	293	3	56
3	5 July	1	39	122	122	122	1	188
	7 July	2	38	72	72	72	1	114
	8 July	3	ND[2]	---	---	---	---	---
	13 July	4	41	108	108	108	2	158
	15 July	5	41	70	70	70	3	104
	19 July	6	40	84	84	84	2	126
Total			199	456	456	456	9	138
All	5 July	1	132	192	192	182	2	87
	7 July	2	139	147	147	141	3	64
	8 July	3	104	72	71	61	0	42
	13 July	4	137	203	202	194	2	89
	15 July	5	148	146	146	135	3	59
	19 July	6	143	172	172	168	3	72
Total			803	932	930	881	13	70

[1] CPUE = number of Arctic grayling caught per hour.
[2] ND = not done.